December 22, 2006

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Project:	RAC II Contract No.: 68-W-98-210 Work Assignment: 146-RICO-02PE
Doc. Control No.:	3223-146-TT-LISE-06467
Subject:	Technology Literature Search Technical Memorandum Old Roosevelt Field Contaminated Groundwater Site Remedial Investigation/Feasibility Study Garden City, New York

Dear Ms. Kwan:

CDM Federal Programs Corporation (CDM) is pleased to submit the Technology Literature Search Technical Memorandum for Old Roosevelt Field Contaminated Groundwater Site in Garden City, New York. The technologies discussed in this technical memorandum will be included in the Feasibility Study for the site, which will be started in mid-January 2007. Per your request, the technical memorandum will be distributed to recipients on a list provided to CDM.

If you have any comments concerning this submittal, please contact me at (212) 785-9123 or Ms. Susan Schofield at (203) 262-6633.

Very truly yours,
CDM FEDERAL PROGRAMS CORPORATION

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TECHNOLOGY LITERATURE SEARCH
TECHNICAL MEMORANDUM
OLD ROOSEVELT FIELD
CONTAMINATED GROUNDWATER SITE
GARDEN CITY, NEW YORK

Work Assignment No.: 146-RICO-02PE

Prepared for:
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Date Prepared	: December 22, 2006

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Acronyms

AS	air sparging
bgs	below ground surface
CO_2	carbon dioxide
CDM	CDM Federal Programs Corporation
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
DCE	dichloroethene
DO	dissolved oxygen
EAB	Enhanced Anaerobic Bioremediation
EPA	Environmental Protection Agency
ft/d	feet per day
ft^2/d	square feet per day
GRAs	General Response Actions
GAC	granular activated carbon
ISCO	In-Situ Chemical Oxidation
K_{oc}	organic carbon partition coefficients
MCL	Maximum Contaminant Level
mgd	million gallons per day
msl	mean sea level
MNA	monitored natural attenuation
NCDH	Nassau County Department of Health
NCDPW	Nassau County Department of Public works
NYSDEC	New York State Department of Conservation
PCE	tetrachloroethylene
ppbv	parts per billion per volume
PRBs	Permeable Reactive Barriers
Redox	oxidation reduction potential
RI/FS	Remedial Investigation/ Feasibility Study
SSD	sub-slab depressurization
SVE	Soil Vapor Extraction
SVP	screening vertical profile boring
TCA	1,1,1,-trichloroethane
TCE	trichloroethene
the site	Old Roosevelt Field Contaminated Groundwater site
US	United States
USGS	United States Geological Survey
UV	ultraviolet
VC	vinyl chloride
VOCs	volatile organic compounds
ug/L	micrograms per liter
ug/m^3	micrograms per cubic meter

Section 1
Introduction

This Technology Literature Search technical memorandum was prepared in accordance with Section 5.8.1 of the CDM Federal Programs Corporation (CDM) Final Work Plan dated December 10, 2004 for the Old Roosevelt Field Contaminated Groundwater Site (the site) located in Garden City, New York (Figure 1-1). This report presents an evaluation of viable technologies that may be applicable to the contaminants and conditions at the site. Applicable technologies identified for the site may require a treatability study. A treatability study would determine the actual suitability of these technologies to site conditions and problems, and would provide site-specific information for cost estimates. This report also presents a discussion of whether the viable technologies that may be applicable to the site would require a treatability study.

1.1 Site Description

The Roosevelt site is an area of groundwater contamination within the Village of Garden City, in central Nassau County, New York. The site is located on the eastern side of Clinton Road, approximately 0.6 mile south of the intersection with Old Country Road. The Roosevelt site includes a thin strip of open space along Clinton Road (known as Hazelhurst Park), a large retail shopping mall with a number of restaurants, and a movie theater. Several office buildings (including Garden City Plaza) are on the perimeter, sharing parking space with the shopping mall. Two active pumping wells (10 and 11) are located in the vicinity. Two recharge basins are directly east and south of the mall area. The eastern basin, Pembrook, is on property owned by the mall. The basin to the south is Nassau County Storm Water Basin number 124 (Figure 1-2).

1.2 Site History

The Roosevelt site was used for aviation activities from 1911 to 1951. The United States (U.S.) military began using the Hempstead Plains field prior to World War I to train Army and Navy officers and as a training center for military pilots. In 1918, the Army changed the name of the airfield to Roosevelt Field.

After the first World War, the U.S. Air Service authorized aviation-related companies to operate from Roosevelt Field, but maintained control until July 1, 1920, at which time the Government sold its buildings and relinquished control of the field for commercial aviation uses.

During World War II, Roosevelt Field was again used by both the Army and Navy. The Army used the field to provide airplane and engine mechanics training to Army personnel. As of March 1942, there were 6 steel/concrete hangars, 14 wooden hangars, and several other buildings at Roosevelt Field, which were used to receive, refuel, crate, and ship Army aircraft. In November 1942, the Navy Bureau of Aeronautics established a modification center at Roosevelt Field to install British equipment into U.S. aircraft for the British Royal Navy. The Navy was responsible for aircraft repair and maintenance, equipment installation, preparation and flight delivery of lend-lease aircraft, and metal work required for the installation of British modifications. The facility also performed salvage work of crashed Royal Navy planes. The Navy vacated all but six hangars shortly after the war ended. In August 1946, Roosevelt Field again operated as a commercial airport until it closed in May 1951.

Soon after the airfield closed, industrial plants for precision electronic instruments were under construction at Roosevelt Field and further development was planned. The large Roosevelt Field Shopping Center was constructed at the site and opened in 1957. Three of the old Navy hangars remained standing until some time after June 1971, with various occupants, including a moving/storage firm, discotheque, amusement center, and bus garage.

1.3 Physical Characteristics of the Study Area

Surface Features
The site is located within the Atlantic Coastal Plain of New York. The topography of the central portion of Nassau County is characterized by a gently southward-sloping glacial outwash plain. The site is flat to gently undulating with slopes from approximately 100 feet above mean sea level (msl) at the northern edge of the site (along Old Country Road) down to approximately 70 feet above msl about 4,000 feet south-southwest of Roosevelt Field, along Clinton Road.

Geology
The site is located within the Atlantic Coastal Plain Physiographic Province. The geology of Long Island is characterized by a southeastward-thickening wedge of unconsolidated sediments unconformably overlying a gently-dipping basement bedrock surface. The wedge ranges in thickness from zero feet beneath Long Island Sound to the north, on the submerged western margin of the Coastal Plain, to more than 2,000 feet under the southern shores of Long Island. In the vicinity of the Roosevelt site the sedimentary units thicken from about 800 feet at the northern edge of the Town of Hempstead to approximately 1,500 feet thick beneath the barrier islands.

The geologic units at the site consist of:

- Basement - Precambrian to Early Paleozoic igneous or metamorphic bedrock
- Raritan Formation - Cretaceous Lloyd Sand Member (sand and gravel) and the overlying Raritan Clay Member (clay and silt as a confining layer)
- Magothy Formation - Cretaceous fine to medium quartz sand, interbedded clayey sand with silt, clay, and gravel interbeds or lenses, Interbeded clay is more common toward the top of the formation
- Pleistocene Deposits - only the Upper Glacial deposits are identified at the site. the Upper Glacial deposits are composed mainly of stratified beds of fine to coarse-grained sand and gravel; thin beds of silt and clay are interbedded with coarse-grained material

The Upper Glacial deposits and the Magothy Formation are the geologic units of interest for the Roosevelt site.

Hydrogeology
The Upper Glacial and Magothy aquifer is unconfined and form a single aquifer unit, although with different properties. They are the most productive and heavily utilized groundwater resource on Long Island. Average transmissivities are 32,160 square feet per day (ft^2/d) for the Magothy aquifer and 26,800 ft^2/d in the Upper Glacial aquifer. Average hydraulic conductivities are 228 feet per day (ft/d) in the Upper Glacial and 174 in the Magothy (Krulikas 1987b).

Horizontal velocity in the Upper Glacial aquifer generally ranges from 1 to 2 ft/d. Based on site-specific values, the average horizontal flow rate for the Magothy is 1.8 ft/d, although literature values are estimated to be 0.3 ft/d. Based on measurements in the eight multi-port wells and the existing wells, groundwater flow is to the south. Pressure measurements in the ports indicate the vertical groundwater flow is downward.

The depth to the water table at the site was between 27 and 37.6 feet below the ground surface (bgs) during the RI groundwater sampling events. The general horizontal groundwater flow trend is to the south. A small groundwater sink is observed in the vicinity of SVP-2. Based on Round 1 data of the RI for the shallow aquifer, the groundwater flow gradient is 0.00156. Given this flow gradient, a porosity of 0.15, and the conductivity for the Magothy aquifer (approximately 174 ft/d), the flow rate is estimated to be 1.8 ft/d.

Water level elevation data from the multi-port wells installed during the RI provided an opportunity to evaluate vertical groundwater flow within each well location. In all multi-port wells, the vertical groundwater flow is downward. The five multi-port wells in the mall area have similar vertical gradients, with the differences between water levels in the shallow and deep ports within each well ranging from 1.8 - 2.9 feet. Further to the south, the vertical gradients become larger: 3.2 feet in SVP-7; 8.2 feet in SVP-8, and 9.7 in SVP-6. The higher vertical gradients in SVP-8 and SVP-6 are most likely caused by pumping at the Hempstead wells, about a block from the multi-port wells.

Surface Water Hydrology
No naturally-occurring surface water bodies are present in the vicinity of the Roosevelt site. Almost the entire site area is paved or is occupied by buildings. Any runoff is routed into storm water collection systems and commonly is discharged directly to either dry wells or recharge/detention basins. In general, the sandy nature of the natural soils on Long Island promotes fast infiltration of precipitation (rainwater) from the ground surface.

The Pembrook recharge basin and two Nassau County recharge basins are man-made water table recharge basins located on or near the site. One of the Nassau County basins is located immediately south of the Pembrook Basin, approximately 1,500 feet southwest of the Roosevelt Field Shopping Center; the other county recharge basin is located about 1,000 feet southeast of the shopping center (see Figure 1-2). The privately-owned Pembrook Basin formerly received cooling water discharge (Eckhardt and Pearsall 1989). Currently it appears to receive surface water runoff during storm events. The Nassau County basins receive storm runoff from the municipal storm water collection system.

1.4 Site Investigation

In the late 1970s and early 1980s, tetrachloroethene (PCE) and trichloroethene (TCE) were detected in pumping wells 10 and 11. Wells 10 and 11 were installed in 1952, at what had been the southwest corner of the airfield, and were put into service in 1953. PCE and TCE concentrations in these two wells reached their highest levels during the mid-to late 1990s, and have steadily declined since then.

Several investigations have been performed at the site or near the site by Nassau County Department of Health (NCDH), Nassau County Department of Public Works (NCDPW), United State Geological Survey (USGS), and New York State Department of Environmental Conservation (NYSDEC). These investigations confirmed the groundwater contamination at the site by chlorinated volatile organic compounds (VOCs) emanating from the Roosevelt Field area, but no soil contamination were found at the site.

In 2005 and 2006, CDM, under the work assignment with EPA, performed a remedial investigation (RI) at the site. As part of the RI, a hydrogeological investigation and a source area soil gas investigation were conducted.

<u>Hydrogeological Investigation</u>

- Conducted a geophysical utility survey
- Collected discrete-depth groundwater screening samples for 24-hour turnaround VOC analysis to assist in selection of multi-port well screen intervals in 8 wells
- Conducted borehole natural gamma logging in multi-port well borings
- Installed and developed 4-inch diameter outer screen and casing assemblies to support the multi-port well equipment
- Installed multi-port well equipment
- Collected two rounds of hydrostatic pressure and synoptic water level measurements
- Re-developed select existing monitoring wells
- Collected groundwater samples from multi-port monitoring wells and select existing monitoring wells

<u>Source Area Soil Gas Investigation</u>

- Conducted geophysical utility survey
- Installed temporary soil gas points and conducted soil gas screening in the source area at 158 locations at two depths: 15 feet bgs and 35 feet bgs, and the

total VOCs were measured using a ppbRAE

- Collected 36 soil gas samples with canister adjacent to three office buildings and along Clinton Road (Hazelhurst Park) for VOC analysis using EPA method TO-15.

1.5 Nature and Extent of Contamination

Source

It is possible that chlorinated solvents were used at Roosevelt Field during and after World War II, since chlorinated solvents, such as PCE and TCE, have been widely used for aircraft manufacturing, maintenance, and repair operations since about the 1940s. The wasted PCE and TCE might have been directly discharged to the ground surface, as a common practice at that time, and contaminated the groundwater.

Groundwater

During the RI, the highest levels of PCE and TCE (350 and 280 micrograms per liter (μg/L, respectively) are concentrated at multi-port well SVP-4, at elevations ranging from approximately -221 to -156 feet below msl (approximately 250 to 310 feet bgs). It should be noted that the SVP-4 location was selected for monitoring because a distilling well/drain field was operated in the area during the 1980s, to dispose of cooling water contaminated with the site-related VOCs. The next highest levels (TCE 260 μg/L in Round 1 groundwater sampling) occur downgradient (to the south) of SVP-4 in existing well 10019, at a slightly shallower depth; and at the two active pumping wells 10 (PCE 270 μg/L in Round 1 and TCE 220 μg/L in Round 2) and 11 (PCE 58 μg/L in Round 2 and TCE 160 μg/L in both rounds), approximately 150 feet deeper than the highest contaminant zone in SVP-4. These four wells comprise the core of the PCE/TCE contaminant plume.

Pumping wells 10 and 11 each have a capacity to pump approximately one million gallons per day (mgd) of groundwater from the Magothy aquifer, and as a result, have a direct influence on the localized groundwater flow and corresponding contaminant plume. Pumping has created a significant cone of depression and has limited the downgradient migration of contamination. Groundwater flow and contaminant movement is downward and south from contaminant sources to the active pumping wells.

Further downgradient of the active pumping wells, PCE and TCE contaminant levels in the most downgradient multi-port well (SVP-8) are seen at shallower depths than at the plume core in the source area. This contamination at the downgradient wells is not considered to be related to the site.

Soil Gas

Of all the soil gas total VOC readings by ppbRAE collected at approximately 15 feet bgs, 85 percent were at or below 10 parts per billion per volume (ppbv); 8 percent were between 11 and 50 ppbv, and 4 percent were between 51 and 100 ppbv. Five of the soil gas samples had total VOC readings above 100 ppbv. The highest detection was 534 ppbv located west of Garden City Plaza Building 200.

Of all the soil gas total VOC readings by ppbRAE collected at approximately 35 feet bgs, 83 percent were at or below 10 ppbv; 9 percent were between 11 and 50 ppbv, and 2.5 percent were between 51 and 100 ppbv. Nine of the samples had total VOC readings above 100 ppbv. The highest detection was 494 ppbv, at the same location with highest VOC readings at 15 feet bgs, west of Garden City Plaza Building 200.

Soil gas samples collected in canisters were compared to the soil gas screening criteria. Only TCE, with a criterion of 2.2 micrograms per cubic meter ($\mu g/m^3$), exceeded the criteria based on the EPA 2002 draft document for *Evaluating the Vapor Intrusion to Indoor Air Pathway from Groundwater and Soils* for the risk level of 10^{-6}. One sample near Garden City Plaza building 200 (SGRF-25 at 23 $\mu g/m^3$) and three samples collected along Hazelhurst Park (adjacent to Clinton Road) had TCE detections that exceeded the criterion (SGHP-2 at 3.9J, SGHP-3 at 12, and SGHP-4 at 3J $\mu g/m^3$). It should be noted that the contract required detection limit for TCE exceeded the screening criterion; it ranged from 5.2 to 5.8 $\mu g/m^3$.

The soil gas survey indicated a few areas with elevated soil gas, but levels do not indicate the presence of any residual contamination sources in the vadose zone.

1.5 Technical Memorandum Organization

The purpose of this technical memorandum is to discuss viable technologies that may be applicable to the contaminants of concern and conditions at the site and to identify the need to perform a treatability study early in the Remedial Investigation/ Feasibility Study (RI/FS) process.

The Technical Memorandum contains three sections:

Section 1 — Introduction - The introductory section lays out site conditions, site contaminants, and the format for the technical memorandum.

Section 2 — Technology Evaluation - This section presents an evaluation of applicable treatment technologies, including institutional and engineering controls, monitored natural attenuation (MNA), containment technologies, extraction technologies, ex-situ and in-situ treatment technologies, and potential discharge/disposal technologies.

Section 3 — Evaluation of Treatability Study Requirements - This section discusses the technology evaluation results and identifies if there is a need to perform a treatability study.

Section 2
Technology Evaluation

In order to evaluate the need to perform a treatability study, potentially applicable technologies for the site's contaminants are identified and briefly evaluated in this section. General Response Actions (GRAs) for contaminated groundwater were identified as the first step in the technology evaluation. GRAs are broad remedial actions that are applicable to the site conditions. The GRAs identified for use at the site include institutional and engineering controls, MNA, containment, extraction, in-situ treatment, ex-situ treatment, and discharge.

Following the development of GRAs, one or more technology types were identified for each of the GRA category. This section provides a brief description and evaluation of the remedial technologies that have been identified, using various databases, technical reports, and publications. These technology types and process options were evaluated on the basis of two of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) evaluation criteria: effectiveness and implementability. The third criterion, relative cost, will be reviewed in the FS. Brief definitions of effectiveness and implementability, as they apply to the screening process, are provided below.

- <u>Effectiveness</u> - This evaluation criterion focuses on: 1) the effectiveness in extracting, treating and/or handling by other means (e.g., in situ treatment or natural attenuation) the estimated volumes of contaminated groundwater, and the ability to meet the remediation goals; 2) the potential impacts to human health and the environment during the construction and implementation phases; and 3) how proven and reliable the process options are expected to be with respect to the contaminants and conditions at the site.

- <u>Implementability</u> - This evaluation criterion includes: 1) the technical and administrative feasibility of implementing the remedial system components; and 2) the amount of space needed for treatment and disposal facilities, piping and discharge runs, the availability of space, accessibility, and available vendors.

2.1 Institutional and Engineering Controls

Institutional and engineering controls do not reduce the toxicity, mobility, and volume of contamination, but can be implemented to reduce the probability of exposure to contaminated groundwater. Institutional controls consist of administrative actions which control use of the site. Engineering controls consist of installation of engineering systems to reduce the human exposure to contaminants. Institutional and engineering controls generally require long-term monitoring of contaminant concentrations. Typical institutional/engineering controls are discussed below.

2.1.1 Deed Restrictions

Deed restrictions are regulatory actions which are used to prevent certain types of uses for areas at the site where direct exposure to contaminated soil or groundwater (dermal or ingestion) or inhalation of contaminants partitioned from soil or groundwater represents unacceptable human health risk. Deed restrictions may be used to prevent the installation of drinking water wells and the construction of ponds fed by groundwater, or to limit access to building basements where vapor intrusion occurred. In addition, deed restrictions may be used to limit areas of new construction.

Effectiveness - Deed restrictions may effectively restrict future site uses or activities that may result in direct contact with contaminated groundwater or soil gas. The effectiveness of deed restrictions is dependent on proper enforcement. Deed restrictions, however, will not reduce the migration and the associated environmental impact of the groundwater or soil gas contamination.

Implementability - Deed restrictions may be implemented through the administrative system such as Nassau County or the Village of Garden City. Deed restrictions limit the current and future land use options as long as the contamination exists at unacceptable levels, and may be difficult to enforce over the long term. Deed restrictions may be used in addition to remediation activities, as a protective measure to prevent exposure to contaminants during remediation.

2.1.2 Long-term Monitoring

Long-term monitoring includes periodic sampling and analysis of groundwater. This program would provide an indication of the movement of the contaminants or of the progress of remedial activities.

Effectiveness - Long-term monitoring alone would not be effective in reducing the contamination level. It would not alter the risk on human health and effect on the environment. Long-term monitoring would be effective in providing information on site conditions to decision makers.

Implementability - Groundwater monitoring is a proven and reliable process, and could be easily implemented. All monitoring wells are easily accessible for sample collection.

2.2 Monitored Natural Attenuation

MNA refers to the remedial action that relies on naturally occurring attenuation processes to achieve site-specific remediation goals within a reasonable time frame. Natural attenuation processes that reduce contamination concentrations in groundwater include destructive (biodegradation and chemical reactions with other subsurface constituents) and nondestructive mechanisms (dilution, dispersion, volatilization, and adsorption).

Biodegradation is typically the most significant destructive attenuation mechanism. Chlorinated solvents, such as PCE and TCE, attenuate predominantly by reductive dechlorination under anaerobic conditions. The primary reductive dechlorination pathway for PCE/TCE to non-toxic ethene is given below:

PCE → TCE → dichloroethene (DCE) → vinyl chloride (VC) → Ethene/Methane or carbon dioxide (CO_2)

The reductive dechlorination process requires an adequate supply of electron donors. The existence of other electron acceptors, such as oxygen, nitrate/nitrite, ferric iron, or sulfate inhibits the dechlorination process. The highest reductive dechlorination rates have been observed under highly reducing conditions associated with methanogenic reactions.

By analyzing biogeochemistry data, distribution of electron acceptors (e.g., nitrate/nitrite, sulfate/sulfide, ferrous/ferric iron concentrations), metabolic by-products, and the contaminant distribution and time-trend, it is possible to determine whether active biodegradation of the chlorinated solvents is occurring through reductive dechlorination processes.

Effectiveness - MNA is an effective remediation approach for sites that have demonstrated utilization of natural mechanisms to minimize or prevent the further migration of groundwater contamination. Based on the review of the site RI data, it appears that biodegradation of chlorinated solvents likely occurred and may be occurring at limited levels at the core of the contaminant plume. *Cis*-1,2-DCE was detected in wells SVP-4, 10019, 10 and 11 at slightly higher concentrations than in other monitoring wells. The dissolved oxygen (DO) and oxidation-reduction potential (Redox) measurements in SVP-4 indicate anoxic groundwater conditions. Further evaluation will be conducted during the FS to determine whether natural biodegradation is occurring at this site.

Implementability - MNA is considered to be easily implementable. Materials and services necessary to model and monitor the contaminant dynamics are readily available. Site restrictions and/or institutional controls may be required as long-term control measures as part of the MNA alternative.

2.3 Containment Technologies

Containment actions use physical, low permeable barriers to minimize or eliminate contaminant migration. Containment technologies do not involve treatment to reduce the toxicity or volume of contaminants. The response action requires long-term monitoring to determine whether containment actions are performing successfully. The commonly used containment technologies include slurry walls and sheet pile barriers.

2.3.1 Slurry Walls

Slurry walls are constructed by pumping low-permeable slurry, typically consisting of either a soil-bentonite or cement-bentonite mixture, into an excavated trench. Excavation can be completed using a long-arm excavator and a clam shovel to meet the required depth. Slurry would be pumped into the hole during the course of excavation to keep the sidewalls from heaving.

Effectiveness - Slurry walls would be effective to achieve hydraulic control. The walls may deteriorate over time due to the presence of chlorinated VOCs at this site, including PCE. Upon the completion of remedial activities, the walls would remain in place and continue to influence groundwater flow patterns on a localized scale.

Implementability - Typical slurry wall applications reach installation depths of about 30 to 40 feet bgs, based upon practical limitations associated with excavator trenching. However, slurry walls can be installed to depths exceeding 100 feet bgs using a clam shovel at a higher unit cost. At the site, groundwater contamination is between 150 to 400 feet bgs, therefore, slurry walls are not applicable due to the limitation of implementation.

2.3.2 Sheet Pile Barriers

Sheet pile walls are constructed by driving or vibrating sections of steel sheet piling into the ground. Each sheet pile section is interlocked at its edges, and the seams are often grouted to prevent leakage.

Effectiveness - Sheet pile walls are effective at providing hydraulic source control. Sheet pile barriers may deteriorate over time under acidic or alkaline conditions, or in the presence of chlorinated VOCs, such as PCE, that exist at this site.

Implementability - Typical sheet pile wall applications reach installation depths of about 80 feet bgs, based upon practical limitations associated with installation. Sheet pile walls can be installed to depths exceeding 100 feet bgs at a higher unit cost. At the site, groundwater contamination is between 150 to 400 feet bgs, sheet pile barriers are not applicable due to the limitation of implementation.

2.4 Extraction Technologies

Groundwater extraction can be implemented to obtain hydraulic controls and prevent further migration of contaminants. Extracted groundwater would subsequently be treated through ex-situ treatment and discharge.

2.4.1 Extraction Wells

This technology involves installation of extraction wells within areas of interest to provide hydraulic controls.

Effectiveness - This conventional technology is effective in providing hydraulic control, for sites where the hydrogeology is well understood and the pumping rate necessary to maintain hydraulic control is sustainable. For this site, the current pumping wells 10 and 11 are believed to have limited migration of contaminants downgradient. Aquifer pumping test and groundwater modeling could be conducted to evaluate the optimal locations and operation conditions for extractions wells to control the migration of the contaminant plume.

Implementability - Extraction wells are implementable. The equipment and materials are readily available.

2.5 Onsite Ex-Situ Treatment Technologies

If groundwater extraction is selected as a remediation option, an ex-situ treatment system would be required to remove contaminants from the groundwater before discharging on site. The primary advantage of ex-situ treatment over in-situ treatment is better process control (i.e., the ability to monitor and continuously mix the groundwater) which results in more uniform and effective treatment. Several ex-situ treatment technologies were identified as potentially applicable at the site. These technologies, discussed below, are separated into aqueous phase treatment and vapor-phase treatment/discharge.

2.5.1 Aqueous-Phase Treatment

2.5.1.1 Air Stripping

Air stripping is a physical mass transfer process that uses clean air to remove dissolved VOCs from water by increasing the surface area of the groundwater exposed to air. Commonly used systems include the countercurrent packed column, multiple chamber fine bubble aeration systems, and low profile sieve tray air strippers. In a countercurrent packed column, contaminated groundwater is sprayed through nozzles at the top of the column, flowing downward through packing materials. In a low profile sieve tray air stripper, contaminated groundwater flows across the surface of a series of perforated trays. In both systems, clean air is forced into the system by a blower in a direction opposite to groundwater flow, i.e., from the bottom, flowing upward. In a multiple chamber fine bubble aeration system, contaminated groundwater flows through aeration tank chambers, and air is introduced at the bottom of each chamber through diffusers forming thousands of fine bubbles. As the fine air bubbles travel upward through the water, mass transfer occurs at the bubble/water interface. System efficiency increases with decreasing bubble diameters.

In general, the water stream out of an air stripper can be discharged to surface water or groundwater. The vapor effluent would likely require additional treatment (e.g., carbon adsorption) before discharge to the atmosphere.

Effectiveness - Air stripping is effective in removing volatile contaminants from water. Air stripping is proven to successfully remove TCE and PCE from water, because of their high Henry's law constants. Therefore, air stripping is an applicable treatment option for this site.

Implementability - This technology is implementable. The equipments and materials are readily available.

2.5.1.2 Liquid-Phase Activated Carbon Adsoption

Carbon adsorption can be used to treat contaminated groundwater directly. Contaminated groundwater can be pumped through vessel(s) containing granular activated carbon (GAC) to which contaminants are adsorbed and are, thereby, removed from the groundwater. When the concentration of contaminants in the effluent exceeds a pre-established value (breakthrough concentration), the GAC is removed for regeneration or disposal.

Effectiveness - Carbon adsorption is effective in removing contaminants with moderate or high organic carbon partition coefficients (K_{oc}) from groundwater. Carbon adsorption is not effective in removing vinyl chloride, a degradation product of TCE and PCE. The process is susceptible to biological and inorganic fouling and may require pretreatment steps such as pH adjustment and suspended solids removal.

Implementability - Activated carbon adsorption is implementable and a proven technology. The equipment and materials are readily available.

2.5.1.3 Ultraviolet Oxidation

During the ultraviolet (UV) oxidation process, organic contaminants in groundwater are oxidized through addition of strong oxidizers (ozone or hydrogen peroxide) and irradiated with UV light. First, the groundwater is dosed with an oxidizing agent (typically hydrogen peroxide) and then passed through a chamber, where it is exposed to intense UV radiation emitted by UV light bulbs. Oxidation of target contaminants results from direct reaction with the oxidizers combined with UV photolysis. When complete mineralization of PCE/TCE is achieved, the final products include water, carbon dioxide, and chloride.

Pretreatment (e.g., filtration) may be required to remove high turbidity and suspended solids which can interfere with transmission of UV light during treatment. Metals, high alkalinity, and carbonates in the groundwater may also require removal to minimize fouling of the UV oxidation equipment.

Effectiveness - UV oxidation has been demonstrated to be effective in the destruction of chlorinated hydrocarbons (e.g., TCE, PCE, and vinyl chloride). UV oxidation treatment can reduce the VOC concentration of the influent water entering an air stripper to eliminate the need for off-gas treatment from the air stripper. In particular, this system is necessary to reduce concentrations of vinyl chloride, if present, which are not amenable to carbon adsorption treatment.

Implementability - This technology is implementable and is proven, and UV oxidation systems are available from several commercial vendors. In addition, the reagents typically used in the UV oxidation processes (i.e., hydrogen peroxide and ozone) are available or can be generated readily. Minor administrative difficulties are anticipated for implementing this technology; permits may be required for discharge of unreacted ozone (if used) and volatilized contaminants not oxidized in the treatment process.

2.5.1.4 Biological Treatment

Ex-situ biological treatment techniques involve placing groundwater in contact with microorganisms within a biological reactor. The microorganisms are stimulated to grow and use contaminants as food and energy sources. This usually requires the creation of a favorable environment for the microorganisms, by controlling oxygen and nutrients levels, temperature, and pH. Biodegradation of PCE and TCE undergoes reductive dechlorination processes under anaerobic conditions.

Effectiveness - Enhanced anaerobic degradation has been effective in degrading chlorinated solvents.

Implementability - Groundwater at the site is under aerobic condition. There are indicators that at SVP-4, anoxic conditions may exist. It would not be difficult to create anaerobic conditions in the bioreactor. However, biodegradation of PCE and TCE requires time; it would need huge bioreactors to hold the extracted groundwater through the treatment process.

2.5.2 Vapor-Phase Treatment

2.5.2.1 Vapor-Phase Activated Carbon Adsorption

Carbon adsorption can be used to treat the off-gas generated during air stripping. Contaminants in the vapor phase of the off-gas are adsorbed onto the GAC, and removed from the waste stream.

Effectiveness - Activated carbon adsorption is effective in removing PCE, TCE and DCE. It is not effective in the removal of vinyl chloride, an additional treatment method such as potassium permanganate oxidation would be required for sites with significant concentrations of vinyl chloride. At this site, no vinyl chloride has been detected.

Implementability - This technology is implementable and proven, and the equipment and materials are readily available.

2.6 In-Situ Treatment Technologies

Several in-situ treatment technologies were identified as potentially applicable at the site, and are discussed below.

2.6.1 Phytoremediation

Phytoremediation includes processes that use plants, and their associated rhizospheric microorganisms, to remove or degrade contaminants in groundwater. It is considered a biological process even though physical and chemical processes are also part of this technology. Contaminants are removed from groundwater through capture of groundwater for plant use; uptake and accumulation of contaminants; uptake and processing of contaminants through metabolization, mineralization, and transpiration; and rhizospheric degradation via microorganisms.

Effectiveness - This technology is applicable for relatively shallow groundwater (less than 10 feet bgs) and large groundwater plumes with low levels of contamination (high levels of contaminants may be toxic to the plants). The time to achieve remediation may extend over several growing seasons and is highly dependent on climatic conditions at the site. At this site, the contaminants are deep in the subsurface, plant root will not be able to reach the contaminants, so this technology could not be effectively used.

Implementability - This technology is not applicable for the site because contamination is found at depths significantly greater than 10 feet bgs.

2.6.2 Permeable Reactive Barriers

Permeable Reactive Barriers (PRBs) provide in-situ treatment of groundwater and are designed as preferential conduits for contaminated groundwater flow. These reactive barriers differ from highly impermeable barriers, such as grouts, slurries, or sheet pilings, which restrict the movement of groundwater plume. PRBs can be installed as permanent, semi-permanent, or replaceable units across the contaminated groundwater flow path and act as a treatment wall. Natural hydraulic gradients transport contaminants through the strategically placed reactive media. When the contaminated groundwater passes through the reactive zone of the barrier, the contaminants are either immobilized or transformed to less harmful compounds.

Effectiveness - PRBs with zero-valent iron have been demonstrated to effectively degrade chlorinated solvents at many sites. PRBs would require periodic reactivation to retain the effectiveness.

Implementability - PRBs can be installed downgradient, vertically intersecting the contaminated groundwater flow with trenching or well injection. Given the relatively significant depth of the contaminant zone at the site, the use of trenching would not be technically feasible. Placement by injection wells may require a significant number of wells and would be very expensive. PRBs may be implemented at the site, but it is not a very suitable application due to the depth of contamination.

2.6.3 In-Situ Chemical Oxidation

In-Situ Chemical Oxidation (ISCO) is an aggressive approach that involves the injection into the subsurface of chemical oxidants which destroy organic contaminants in groundwater. Complete oxidation of PCE/TCE results in their breakdown into less toxic compounds such as carbon dioxide, water, and chloride. In-situ chemical oxidation can significantly increase the mass transfer between the residual contaminated soil, if present, and groundwater, subsequently destroying the contaminant mass in a shorter period of time. A number of factors affect the performance of this technology, including oxidant delivery to the subsurface, oxidant type, dose of oxidant, contaminant type and concentration, and non-contaminant oxidant demand.

The commonly used oxidants include ozone, Fenton's Reagent, permanganate, activated persulfate, catalyzed percarbonate, etc. Permanganate can oxidize TCE and PCE effectively and is relatively stable in the subsurface. Fenton's reagent, activated persulfate, and catalyzed percarbonate can generate radicals to oxidize contaminants. Radicals can oxidize a wide variety of contaminants. They are non-selective and have extremely short lifetimes. Therefore, effectively delivering the oxidants into the contaminant zones and ensuring that the radicals come into contact with contaminants is a challenge.

Effectiveness - Delivery of the oxidant to appropriate locations is the key element for its success. Oxidant type is somewhat dictated by the contaminant. ISCO is dependent upon achieving adequate contact between oxidants and contaminants, and subsurface heterogeneities can affect delivery of the oxidant. Poor application can result in large pockets of untreated contaminants and the oxidant can be consumed by other oxidizable substrates, natural organics, and reduced metals. In most instances, repeat applications of oxidant is required.

Implementability -ISCO is generally used to treat the contamination sources where soil contamination is present. At this site, the core of groundwater contamination between SVP-4 and pumping wells 10 and 11 occupies a large area to be treated. It would be difficult to implement at the site because ISCO is only able to effectively treat contamination in a small radius of influence from the injection well. A significant number of injection wells would be required and it would not be cost effective to implement this technology at the site.

2.6.4 In-Situ Air Sparging/Soil Vapor Extraction

In-situ air sparging (AS) is a technique in which air is injected into the groundwater for the purpose of removing organic contaminants by a combination of volatilization and aerobic biodegradation processes. It is typically used in conjunction with soil vapor extraction (SVE) to eliminate offsite migration of vapors. This system would employ a number of air sparging wells aligned in a grid pattern, with SVE wells placed between the sparging wells at further spacing to draw in organic contaminants. As air moves up through the groundwater, VOCs partition into the gas phase and are transported to the vadose zone. At the same time, oxygen in the injected air dissolves in the groundwater and may change the groundwater into aerobic condition. PCE does not biodegrade under aerobic condition, but TCE, DCE, and vinyl chloride can biodegrade through an aerobic degradation pathway.

The VOCs transported into the vadose zone would be captured by SVE techniques. SVE wells would be installed above the water table and a vacuum would be applied to the extraction wells to extract the vapor containing VOCs. An off-gas treatment system using vapor phase carbon adsorption may be necessary to limit the release of contaminants to the surrounding air.

Effectiveness - AS/SVE system has been shown to be effective in removing VOCs from the groundwater in a relatively homogeneous subsurface condition. This process is dependent on how well the injected air permeates through the groundwater from the injection point. The ability of the SVE wells to capture the contaminants forced into the unsaturated zone is an important component due to potential risk of VOCs migrating into buildings within the area of contaminated groundwater. The effectiveness of an AS/SVE system at this site would need to be investigated, because the core of contaminant plume is very deep in the subsurface, and overlaid by groundwater with no or very low contamination. It would require a very high injection air pressure, and it may spread the contaminants into uncontaminated or less contaminated areas.

Implementability - An AS/SVE system is generally simple to implement. Specific equipment and experienced vendors are available on the market. However, due to the significant depth of contamination and the site located in a dense populated area, it would be a great challenge to apply AS/SVE technology at the site.

2.6.5 Enhanced Aerobic Bioremediation

Enhanced Anaerobic Biodegradation (EAB) is a groundwater remedial technology designed to facilitate the in-situ biological destruction of chlorinated VOCs over a wide range of concentrations in groundwater. EAB involves the injection of electron donor, nutrients, and potentially dechlorinating microorganisms (i.e., bioaugmentation) into the subsurface to stimulate the natural reactions of microorganisms to detoxify chlorinated solvent contamination in a low organic environment. Recent developments in biochemistry have enabled engineers to control and stimulate multiple redox reactions known to sequentially dechlorinate solvents in groundwater. Additionally, recent observations in the field indicate high concentrations of organic substrate can enhance solubilization and/or desorption from soil and source areas even where substrate delivery is limited.

Effectiveness - EAB has effectively reduced chlorinated VOC contamination levels at many sites. For most sites, natural occurring biological dechlorination reactions are limited by the availability of biodegradable organic carbon (i.e., electron donor) that serves as an energy source for indigenous microorganisms and/or by elevated concentrations of competing electron acceptors that maintain elevated groundwater reducing conditions competitively inhibiting the activity of the dechlorinating microbes. The addition of an electron donor as an energy source for indigenous microorganisms would stimulate the development of reduced groundwater environments that are conducive to dechlorination reactions (i.e., methanogenic conditions), and fuel the dechlorination process itself. For other sites, the extent of VOC dechlorination may be stalled at a biological intermediate such as DCE or vinyl chloride due to the absence of the indigenous microorganisms capable of reductively biodegrading all source and intermediate VOCs to non-toxic compounds. Under this scenario, active dechlorinating microorganisms may be amended to the subsurface through a process termed bioaugmentation.

Implementability - At this site, the daughter compounds (e.g., DCE) have been detected in monitoring wells SVP-4 and 10019, and active pumping wells 10 and 11. In general, the groundwater is under aerobic conditions in this aquifer, but the DO and Redox measurements in SVP-4 indicated anoxic conditions. EAB could be implemented at this site. However, the volume of the contaminant plume is huge, and the vertical distribution of contaminants varies over more than 250 feet from location to location. Delivery of the amendment could be a challenge.

2.7 Discharge

Once groundwater has been treated, it can be disposed on site or off site. Potential on-site and off-site disposal options for groundwater are evaluated below.

2.7.1 On-site Injection

On-site discharge technology involves injecting treated groundwater to the subsurface using a series of wells. Injection requires that the groundwater be treated to meet applicable groundwater standards prior to disposal to the subsurface.

Effectiveness - The effectiveness of this option would rely on proper injection well design and construction, including adequate pipe sizing, proper placement of the wells, and reliable materials of construction, and the subsurface geology. At this site, the sandy soil has very high permeability, on-site injection can be an effective disposal option.

Implementability - The option to discharge treated effluent to a series of injection wells would be easily and readily implementable, given that standard construction methods and materials would be utilized. A minimum of land space would be necessary for this option. The subsurface at this location is also suitable for the installation of injection wells for discharge to the shallow or intermediate aquifers. Some implementability problems can arise during long-term operation of injection wells, such as clogging of screen packs with precipitates or microbial fouling, particularly in high iron conditions. These can be overcome by proper removal of excess iron from the treated water, periodic chlorination of the injected water, and redevelopment and cycling on/off of wells.

2.7.2 On-site Surface Recharge

Treated groundwater can be disposed on site using a surface recharge system which consists of an excavated recharge basin. Recharge basins are shallow ponds that allow water to infiltrate into the ground gradually, and depending on the permeability of the soil, generally require large surface areas. As with injection wells, on-site recharge requires that the extracted groundwater be treated to meet applicable groundwater standards prior to disposal to the subsurface.

Another method of artificial groundwater recharge would be an infiltration gallery. This system would be developed as a series of perforated pipe galleries laid underground, which would receive treated groundwater from the onsite treatment plant, and disperse the flow evenly through the discharge system, down to the underlying aquifer system.

Another variation to recharge basins would be leaching basins. These are underground covered pits that are typically 5 to 10 feet wide and 10 to 20 feet deep. Although more of them may be needed to handle the flow rate, problems of safety and maintenance associated with recharge basins would be avoided, and they would not require extensive land surface, particularly important in highly developed areas such as this site.

<u>Effectiveness</u> - The effectiveness of this option would rely on the proper construction of the recharge system, including adequate sizing, and use of suitable sand and gravel. The surface area required depends on the extraction rates and types of facilities.

<u>Implementability</u> - This discharge option is readily implementable, as standard construction methods and materials would be utilized. Currently, there are three recharge basin on or near the site that can potentially be used for groundwater discharge.

Section 3
Evaluation of Treatability Study Requirements

In order to evaluate the need for performing a treatability study, this technical memorandum presented an evaluation of viable technologies that may be applicable to the contaminants of concern and conditions at the site. As the first step, applicable GRAs identified include institutional/engineering controls, MNA, extraction, in-situ treatment, ex-situ treatment, and discharge. One or more technology types were then identified and evaluated based on effectiveness and implementability, for each of the GRA categories.

Technologies that are suitable to the site may require treatability studies to better estimate costs and performance capabilities. Treatability studies would determine the suitability of remedial technologies to site conditions and problems and obtain site-specific parameters that can be used for remedial design. The three levels of treatability studies are laboratory screening, bench-scale testing, and pilot-scale testing. The laboratory screening is used to establish the validity of a technology to treat a waste and is normally conducted during the FS. Bench-scale testing is used to identify the performance of the technology specific to a type of waste for an operable unit. Often bench-scale tests are conducted during the FS. Pilot-scale testing is used to provide quantitative performance, cost, and design information for remediation, and is typically performed during the RI/FS.

A treatability study would not be required if any of the extraction, ex-situ treatment, or discharge methods are implemented at the site, because these technologies are all proven methods. A treatability study would be required for the site if in-situ treatment options are selected for the site, because these methods are considered to be innovative technologies.

In-situ treatment options evaluated in this technical memorandum include phytoremediation, PRBs, ISCO, AS/SVE, and EAB. Of these five processes, AS/SVE, ISCO and EAB are applicable, but would not be easily implementable for the site due to the size and depth of the contaminant plume. Phytoremediation is not applicable for the site, because contamination is found at depths greater than 10 feet bgs. PRBs would be difficult to implement at the site due to the significant depth of contamination.